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Anthony Pritzker Environmental Law and Policy Briefs

POLICY BRIEF NO. 1 | July 2011

Under Water: Monitoring and Regulating Groundwater in California

By M. Rhead Enion

Executive Summary The security of California's water supply is under increasing threat. Experts predict that, without serious changes to its water management, the State could face a future of dwindling water availability.

Together, groundwater and surface water make up a single functional natural system. All water, but particularly groundwater, is a public good. If its use is not appropriately valued and regulated, California will see its groundwater unnecessarily depleted. And overuse of groundwater can result other difficulties too, such as land subsidence and the contamination of water supplies by pollutants. To encourage efficient, responsible water use, California must better account for the benefits of water availability and the costs of overuse. Valuing water appropriately will help Californians protect their water supply from pollutants and from overuse, so that California enjoys sufficient, clean water into the future.

Among Western states, only California and Texas still allow the use of groundwater without a permit or other means of tracking and regulating users. And only California law continues to treat groundwater separately from surface water, despite our growing understanding of the physical connections between the two.

Many have argued for better integration of surface water and groundwater policy in California. The California Legislative Analyst's Office (LAO) recently recommended that California "realign the water rights system" and "establish a state-administered water rights system for groundwater."[1] According to the LAO, "reevaluating how groundwater is managed is necessary if it is to achieve its full potential as a reliable source of water."[2]

This paper describes the importance of groundwater to California and re-imagines groundwater management. It recommends a series of steps that California should undertake to achieve the goal of realigning the water rights system for groundwater. Managing California's limited water supply requires first effectively managing California's groundwater. This paper recommends that the State establish an enforceable framework for groundwater monitoring and regulation that will be implemented by regional and local entities, modeled after cooperative federalism models often used for federal-state regulation.

To that end, California should prioritize the following goals:

(A) Establish comprehensive monitoring of groundwater use, groundwater levels and groundwater quality.

California should establish clear guidelines and standards for, and coordinate the collection of groundwater data from, regional and local entities. Monitoring should include accurate metering of all groundwater use. California, with assistance from regional

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and local agencies, should implement real-time monitoring and periodic surveys of groundwater quality. The State should encourage further development and use of satellite monitoring of groundwater. Finally, groundwater data should be integrated into the California Water Plan and be made publicly accessible through a statewide database.

(B) Implement a comprehensive framework for regulation of groundwater, wherein local jurisdictions are given clear guidelines and mandatory management goals.

California should create a template for statewide rules and management goals, and then let local or regional agencies either adopt the statewide template or submit their own equivalent set of rules. Regional or local agencies should identify rights holders and allocate their share of groundwater use for all groundwater basins in California. California must enforce legal restrictions on groundwater use and prevent unmonitored withdrawals. Such legal restrictions should include enforcement of a sustainable yield to prevent overdraft in groundwater basins. As part of California's legal reform, the scientifically unsupportable distinction between percolating groundwater and subterranean streams should be eliminated in the California Water Code. California should also consider adopting a scheme of entitlements and allocations for groundwater rights.

Introduction Over the years, California has taken many steps to increase water conservation and encourage efficient water use. Former Governor Schwarzenegger's 20x2020 plan will reduce urban per capita water use 20% by 2020, saving both water and energy. California's Water Transfers Program encourages farmers to adopt water conservation measures, such as switching to less water intensive crops. But such steps have been hindered by the lack of groundwater management.

Groundwater makes up about 30% to 40% of California's annual water supply. Better monitoring and regulation of groundwater in California is essential for making real progress on water management. Together, groundwater and surface water comprise a single functional natural system. Increased use of one affects supply of the other. Water quality problems in groundwater often find their way into surface water supply.

California and Texas are the only two Western states that allow for groundwater use without a permit. And only California law still considers groundwater separately from surface water. Groundwater is a shared public resource that can be exploited and overused in the absence of meaningful groundwater regulation. Other market failures common to public goods can also result from under-regulation. For example, overuse of groundwater can increase the cost of pumping for all groundwater users and lead to damaging land subsidence.

Efforts to properly value surface water, while laudable, are also increasing the need for better groundwater management. If users are charged more for surface water supplies, they will naturally switch to less regulated groundwater use when groundwater is available, undermining water conservation and efficiency programs. Imposing needed water conservation programs in urban areas will be set back if municipalities turn to exploitation of groundwater resources. Encouraging farmers to switch crops to increase water conservation, or to implement more water-efficient irrigation techniques to reduce runoff pollution will be difficult if groundwater is cheap, available and unregulated.

California cannot meaningfully protect and secure its entire water supply without comprehensively monitoring and regulating groundwater throughout the state. This is not to say that California should impose statewide regulations, overriding years of local groundwater management. Instead, the State should focus on establishing standards, providing expertise, and developing a management framework that will be implemented by regional and local agencies.

Once groundwater regulations and monitoring are in place, the efficacy of other water conservation and efficiency measures will be vastly improved. Agricultural and urban uses can better reflect the true cost of all water use. Groundwater will no longer be simply the substitute for limited surface water supply. And California will be able to better assess the security of its future water supply.

What is Groundwater?

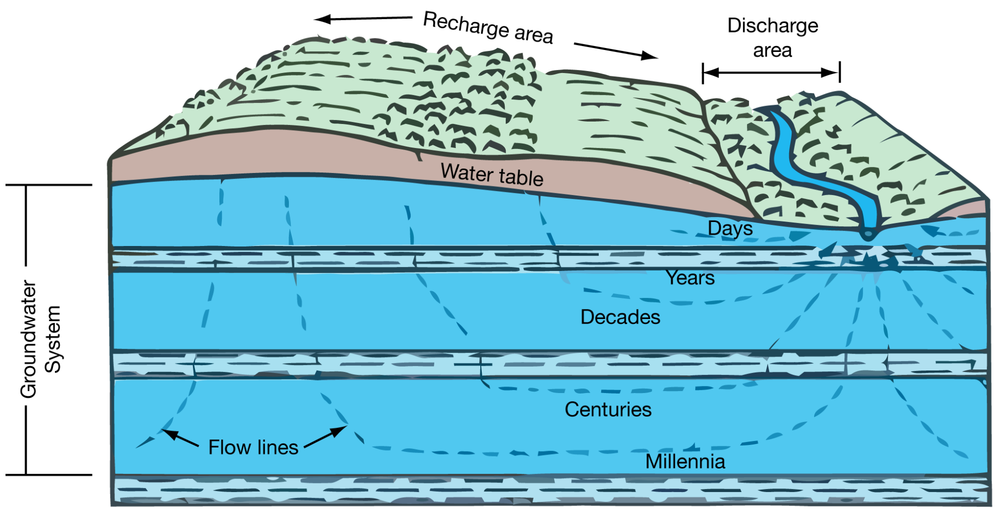
Groundwater is simply water found below ground. Most accessible fresh water on earth is groundwater. Rivers and lakes (surface water) account for less than 1 percent of the world's fresh water.[3]

Groundwater occurs where water fills empty spaces between rocks or sediment underground. The best sources of groundwater—**"aquifers"**—are generally comprised of coarse sand and gravel deposits. Less porous clay and silt deposits—"aquitards"—are poor sources of water. An aquifer (or a stacked series of aquifers) bounded by aquitards or hydrologic features is considered a groundwater basin.

Groundwater movement is complex, but is generally driven by potential energy: the combination of elevation and pressure. Groundwater moves from areas of high to low potential energy, flowing from recharge to discharge areas. **Recharge areas** are areas where precipitation tends to infiltrate into the soil. Often, recharge areas are at higher elevations. **Discharge areas** are areas where groundwater tends to flow back out to the surface. Rivers, streams, and lakes are often found in discharge areas, which tend to occur at lower elevations, such as valleys.

Figure 1 | Groundwater system

Adapted from Waller, U.S. Geological Survey, Ground Water and the Rural Homeowner.



I. California's Groundwater Is An Important Part Of Its Water Supply System

California's limited water supply will be increasingly stressed by population growth and climate change. Climate change may shift precipitation rates in the state. Water from the Colorado River may become less available. California will likely face a decreased ability to pump water through the Sacramento/San Joaquin Delta. Population growth is forecast to increase urban water demand. And years of damage to California's ecosystems will require more water dedicated to environmental mitigation.

California's water supply system depends heavily on groundwater use. Furthermore, groundwater and surface water are often connected, such that use and quality of one impacts the other. Today, overuse of groundwater is a serious problem that threatens the reliability of California's future water supply. Yet groundwater basins also hold the key to efficient, reliable water storage that, if managed properly, could increase future water supply security.

A. Groundwater And Surface Water are Connected

Two characteristics of groundwater are particularly important for water management. First, groundwater is constantly moving. Second, groundwater and surface water are connected. Because of these characteristics, surface water cannot be considered independently of groundwater for long-term water management.

Groundwater constantly moves from recharge areas to discharge areas. [Figure 1: Groundwater system] This movement is slow, from a few feet per year to several feet per day, depending on the region.[4] Some groundwater basins act more like sinks, holding water for long periods of time with low discharge rates. Other basins see high recharge and discharge rates over shorter time periods.

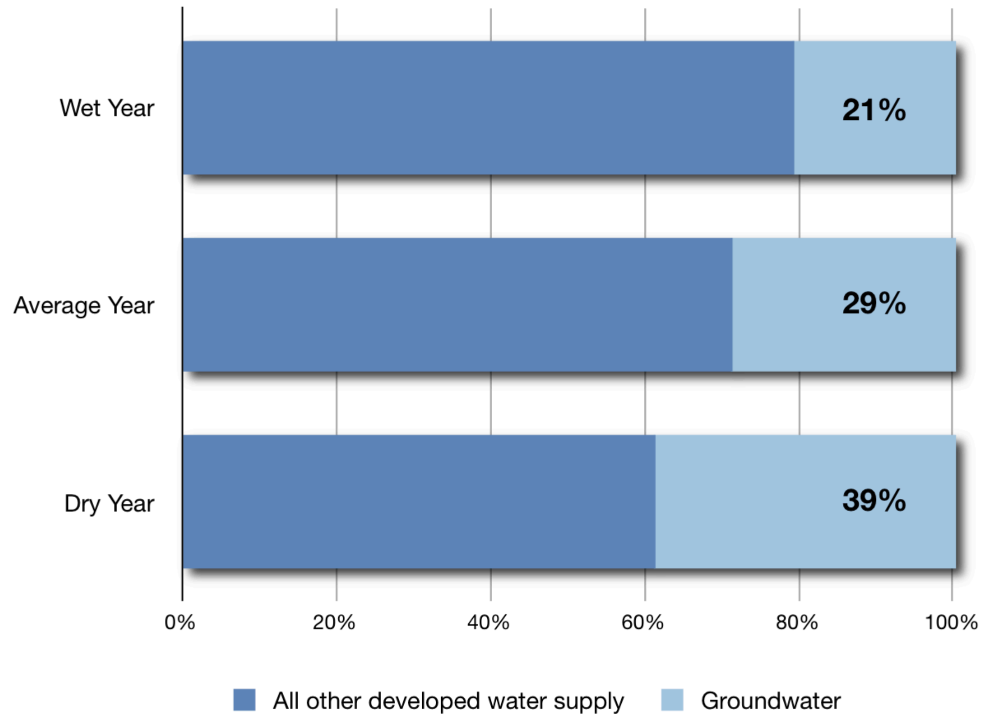
If pollutants flow into an aquifer, the aquifer becomes contaminated. Over time, the contaminated aquifer may leach pollutants back into surface waters. Although the soil does filter many contaminates, aquifers in California have been contaminated by a variety of pollutants.

Most groundwater has a physical connection to surface water through this constant movement. An "empty" groundwater basin, one that holds only a fraction of its total wa-

> "Groundwater comprises about 29% of California's water supply on an average year, and 39% in a dry year."

Figure 2 | Groundwater Contribution to California's Water Supply

Adapted from Freeman, Cal. Legis. Analyst's Office, California Water, 21.



ter capacity, will tend to draw in water from surface streams in the area. A "full" groundwater basin will tend to release water into surface streams.[5] If groundwater pumping lowers the water table, often stream flows will also be lowered.

California has 431 defined groundwater basins, some of which are split into subbasins.[6] The borders of a groundwater basin, however, are not always easily defined. The size of groundwater basins in California varies widely. Many basins span local county and city boundaries. For example, the Turlock subbasin, in the San Joaquin Valley, lies under approximately 347,000 acres in eastern Stanislaus and Merced counties.[7] [Figure 3: Groundwater Basins in California]

B. Groundwater Comprises a Significant Portion Of California's Water Supply

Groundwater is an important component of California's water supply. Groundwater comprises about 29% of California's water supply on an average year, and 39% in a dry year.[8] [Figure 2: Groundwater Contribution to California's Water Supply] 116 groundwater basins in California account for 95% of public wells, 99% of municipal pumping and 90% of agricultural pumping.[9]

Groundwater reliance varies among regions in California. [Figure 4: Variation in groundwater dependence across California] Nearly half of all Californians rely, at least in part, on groundwater supplies.[10] Groundwater can make up 100% of a community's public and irrigation water in some areas.[11] In the Central Valley, groundwater comprises more than 80% of total water use.[12] The Tulare Lake and South Lahontan hydrologic regions use groundwater to meet more than 40% of their local demand.[13] Together, Tulare Lake basin, the San Joaquin River basin, and the Central Coast region are responsible for around two-thirds of all groundwater use in California.[14]

When surface water access is limited, users will turn to groundwater supplies if pos-

Figure 3 | Groundwater Basins in California

From the California Department of Water Resources

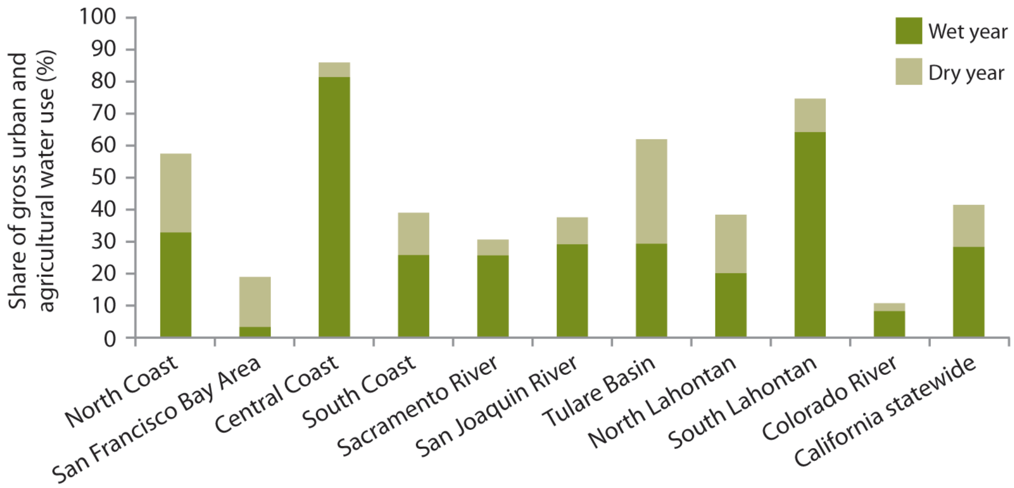
What is a Million Acre-Feet of Water?

An **acre-foot (af)** is the amount of water needed to flood an acre of land one foot deep. One acre-foot is equivalent to 325,851 gallons.

One million acre-feet (maf) of water is enough to irrigate all the grain produced in California each year. It is nearly 12 times the annual water use of San Francisco, 4.5 times the annual water use of San Diego, and 1.6 times the annual water use of Los Angeles.[24]

Figure 4 | Variation In Groundwater Dependence Across California

From Hanak et al., Public Policy Inst. of Cal., Managing California's Water, 79 fig. 2.5.



sible. For example, when Westlands Water District had its surface water allocation cut by 90% in 2009, area farmers turned to groundwater. Groundwater use in the area more than doubled.[15]

C. Groundwater Overdraft Threatens California's Water Supply

In California, groundwater is being withdrawn faster than it is replenished in many aquifers. The state's groundwater basins are replenished at an estimated rate of 12.5 million acre-feet (maf) per year.[17] The state withdraws, on average, 14 maf of groundwater reserves each year.[18] Thus, estimates of groundwater overdraft in California range as high as 2 maf annually.[19] It should be noted that these estimates have a wide margin of error due in part to the absence of quality groundwater use data for California.[20]

A comprehensive assessment of groundwater overdraft in California has not been done since 1980.[21] In 1995, the California Water Plan Update estimated groundwater overdraft at 1.5 maf per year, mostly in the Tulare Lake, San Joaquin River and Central Coast hydrologic regions.[22] A UC Irvine satellite study found that the Central Valley lost 40 maf of groundwater from 1998 to 2010, with the third largest drop in 50 years occurring between 2006 and 2010.[23]

Groundwater overdraft has impacted water quality in some coastal aquifers. Overdrafted aquifers naturally draw in whatever water is adjacent, including seawater. In the Central Coast, the Salinas and Pajaro Basins have been contaminated with seawater intrusion.[25]

Between 2006 and 2009, the Kaweah subbasin aquifer in the San Joaquin basin dropped 50 feet.[26] As a result, some farmers' pumps ran dry. In many places, the costs of pumping and treating groundwater have increased due to overdraft.[27] More than half of the San Joaquin Valley has experienced ground subsidence.[28] In some cases, these dramatic drops in aquifer levels due to overpumping and drought will be irreversible. The land over the depleted basin will subside, shrinking the capacity of the aquifer to store water. As Peter Gleick, co-founder and president of the Pacific Institute, described it, California is "stealing water from the future" by continuing to overdraft its groundwater basins.[29]

D. Many California Aquifers And Rivers Are Impaired By Pollutants

California aquifers and surface water are under threat from a variety of pollutants. The physical connection between many aquifers and surface rivers means that pollution originating in one often migrates to

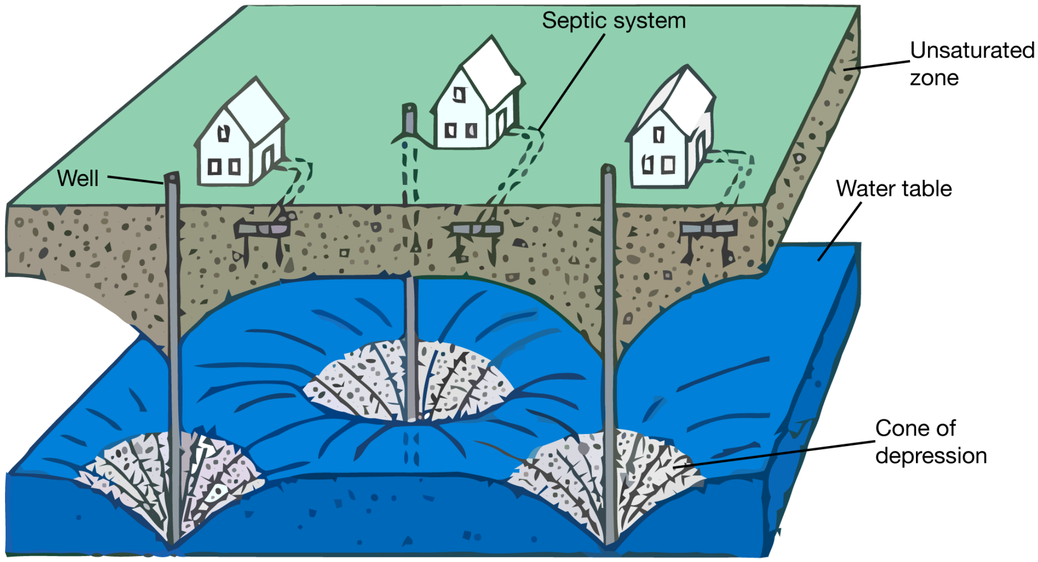
What is Overdraft?

Groundwater overdraft occurs when pumping exceeds the recharge rate of the groundwater basin over a period of years. Over time, overdraft can lead to increased costs of extraction, land subsidence, water quality degradation, and environmental impacts.[16] An overdrafted groundwater basin will tend to absorb more surface water in the area than if the basin were not experiencing overdraft. If the basin experiences overdraft over a long period of time, the land can subside. Besides endangering structures on the land surface, subsidence also reduces the capacity of the groundwater basin.

A related concept is the **"cone of depression"** that occurs when groundwater is withdrawn through a well. [Figure 5: Cone of Depression] When water is pumped out of an aquifer, the water table is lowered around that well, in a cone shape. Multiple wells result in multiple cones of depression. If wells are close to one another, this cone of depression could cause the shallower well to go "dry," if the water table drops below the shallow well. Thus, groundwater withdrawal can have an immediate and significant impact on neighboring wells.

Figure 5 | Cone of Depression

Adapted from Waller, U.S. Geological Survey, Ground Water and the Rural Homeowner.



the other over time. The quality of groundwater, as a major drinking water source for Californians, is of particular concern.

Salinity in aquifers and surface water is a concern throughout California. Excess nutrients from agricultural runoff harms aquatic ecosystems. And toxic chemicals from industry, agricultural and urban water users continue to contaminate California's water supply. [Figure 6: California water quality problems]

High salinity levels are particularly problematic in the southern Central Valley and the Salton Sea.[30] Salt accumulates in soils, water bodies and aquifers. Irrigation and urban wastewater can increase the level of salt .[31] High salinity can harm ecosystems, reduce agricultural productivity and increase urban water costs.[32] In the western San Joaquin and Tulare Basins, salt accumulation has forced farmers to take some of their land out of production.[33]

Nitrogen and phosphorus, two components of fertilizers, can also harm California aquifers and rivers. Excess nutrients result in harmful algal blooms in lakes and streams. Nitrates, a fertilizer byproduct, have accumulated in groundwater in many rural areas, causing problems for local drinking water.[34]

A variety of toxic chemicals have accumulated in California water over the years. Mining activities from a century ago have left a toxic legacy of mercury contamination.[35] Pesticides used in agriculture and landscaping often find their way into streams and aquifers. Selenium runoff from agricultural irrigation poisoned thousands of birds in a Central Valley reservoir thirty years ago, and continues to be a problem today.[36] In urban areas, pharmaceutical drugs are a recent concern to the water quality of urban wastewater discharge.[37]

E. Groundwater Basins Are An Important, Cost-Effective Storage Mechanism For California's Water Supply

The primary concerns for California's water supply relate to both timing and location. About seventy percent of California water supply originates north of San Francisco, while seventy-five percent of California water demand is south of San Francisco.[38] Agricultural demand for water peaks in summer and late fall, but seventy-five percent of precipitation in California occurs in winter.[39]

Climate change models suggest that California may see shifts in precipitation timing that would increase the risk of seasonal

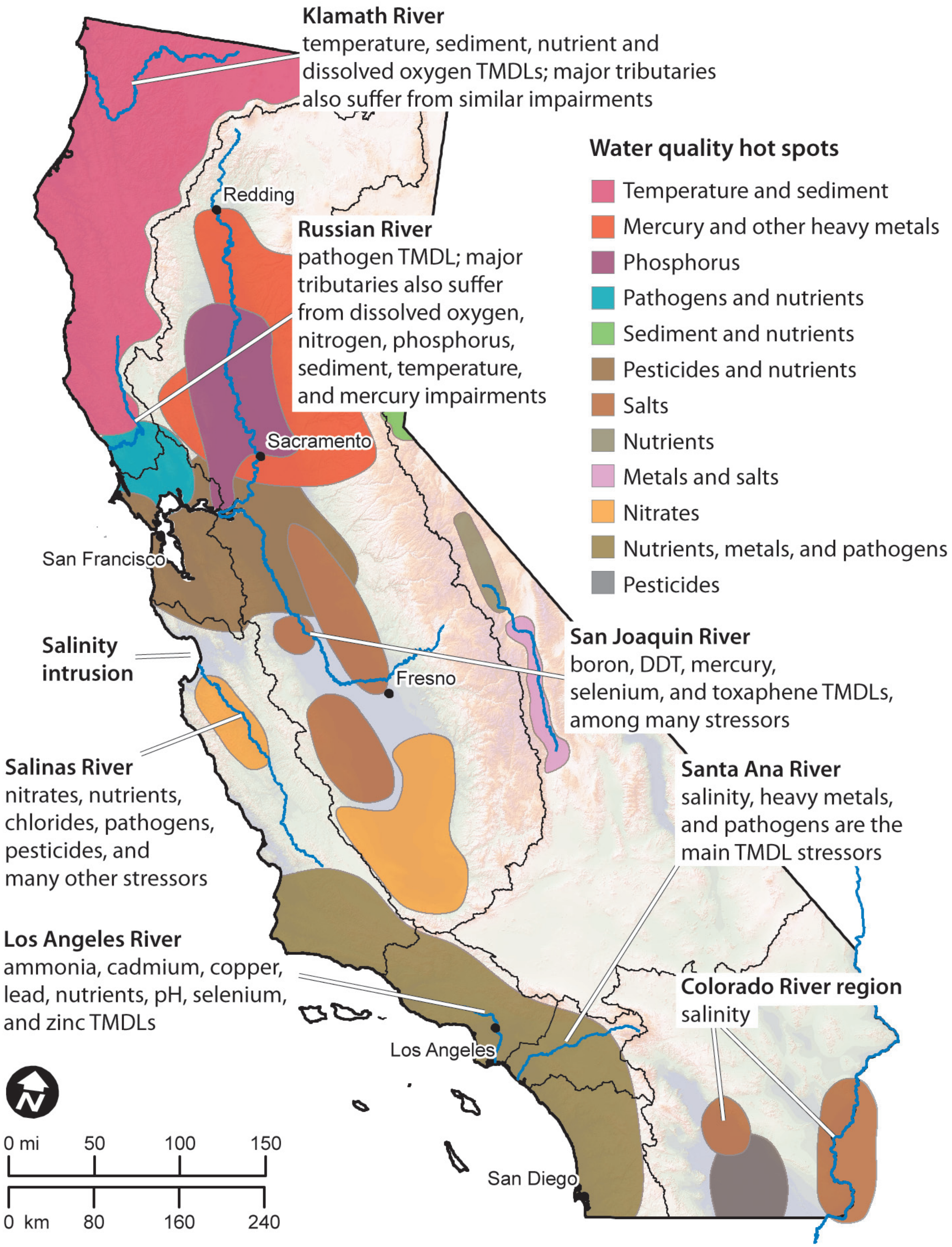
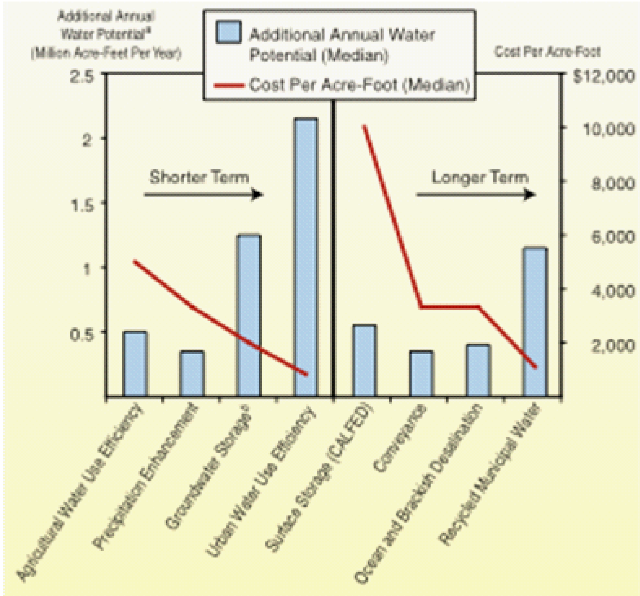


Figure 6 | California water quality problems

From Hanak et al., Public Policy Inst. of Cal., Managing California's Water, 85 fig. 2.7

Figure 7 | Costs of Additional Water Supply

From Freeman, Cal. Legis. Analyst's Office, California Water, 67.



"Managing surface and groundwater together—'conjunctive use'—can improve California's water security."

droughts. The U.S. Bureau of Reclamation forecasts that the Sacramento and San Joaquin basins will see a strong decrease in summer runoff and an increase in winter runoff in the 21st century as warming continues.[40] The end result may be an increase in seasonal droughts, where winter precipitation and runoff is high but summer sees increasingly extreme low precipitation conditions.

California needs to transfer and store water for use during seasonal and multiyear droughts. Because of the high cost of creating new surface reservoirs to store water, some have suggested using groundwater basins as an alternative storage mechanism. [Figure 7: Costs of Additional Water Supply] Some areas have already started using groundwater basins in this manner. Building reservoirs to store surface water has significant costs, due to a combination of initial capital investment, operation and maintenance, and energy consumed to convey water. Sites Reservoir is estimated at $520/acre-foot (af) to store water, plus $150/af to pump the water over the Tehachapi Mountains.[41] Temperance Flat Reservoir is estimated at $720/af.[42]

Much of this cost is due to energy use. Transport and treatment of water uses significant energy, at least 6.5% of California's total electricity use each year.[43] Twenty percent of California's electricity budget is devoted to water consumption.[44] This transport and water treatment emits more than 100 million tons of greenhouse gases, along with harmful particulate matter.[45] The State Water Project (SWP) is California's largest energy user, consuming 2–3% of all electricity used in California.[46] One-third of SWP's annual operating budget is devoted to energy costs.[47] Forty percent of desalination costs can be attributed to energy use.[48] Rising energy is a major driver of increased cost for both SWP and the Metropolitan Water District of Southern California (MWD).[49]

Groundwater basins offer the promise of more cost-efficient storage. Groundwater storage can be either direct or indirect. In direct storage, water is pumped into the aquifer, effectively recharging it and raising the water table. Later, an equivalent amount of water is withdrawn from the aquifer, thereby lower the water table.

Groundwater can also be stored indirectly. In what is called "in-lieu recharge," a user can alternate between surface water and groundwater. For example, a farmer may forgo groundwater and instead use surface water to irrigate his field. All else being equal, this would result in an increase of water in the aquifer. Later, if the farmer uses groundwater in lieu of surface water, the aquifer is depleted but more surface water is available for use elsewhere. When timed correctly, groundwater can be used during droughts and surface water can be used in other times to allow recharge in the aquifer.

Estimates of total groundwater storage capacity in California range from 850 maf to 1,300 maf.[50] Of that amount, usable groundwater storage capacity—defined as the amount that may be economically withdrawn—is estimated at 143 maf to 450 maf.[51]

Managing surface and groundwater together—“conjunctive use”—can improve California’s water security. Models of future California water management suggest that conjunctive use and groundwater banking will be more cost-effective than expansion of surface water storage in reservoirs.[52]

II. California’s Inadequate Groundwater Monitoring and Regulation Threatens its Water Supply

California currently has only limited local regulations on groundwater, with no statewide regulation. Not surprisingly, monitoring and regulation of groundwater withdrawal varies widely between regions.

Without properly quantifying groundwater levels, monitoring groundwater usage, and regulating groundwater withdrawal, California lacks a solid foundation for managing upwards of 30% of its water supply.

“Approximately 2300 local water agencies in California have interests in groundwater.”

Furthermore, California cannot expect to adequately regulate surface water without considering its regulation of groundwater at the same time. Surface water and groundwater are intimately connected. Use of one impacts the quantity and quality of the other.

A. Local Management Of Groundwater Is Inconsistent And Inadequate

California currently has a mix of ad-hoc voluntary local agency regulation and court adjudication of groundwater. Approximately 2300 local water agencies in California have interests in groundwater.[55] In addition, local rules can limit interregional groundwater transfers. The result is inconsistent and often inadequate local management of groundwater. While some local management schemes are innovative and effective, many local districts have been unsuccessful in protecting groundwater.

AB 3030, enacted in 1992, gives local governments the option to create groundwater management plans if they so choose. These plans can include several components, including control of salt water intrusion and contaminated groundwater migration, administration and monitoring of groundwater levels and wellheads, and mitigation of overdraft conditions. In adjudicated basins and certain other managed basins, local groundwater management plans require the approval of the court or managing agency.

Some districts have made significant efforts to regulate groundwater. For example, Orange County Water District has successfully prevented seawater intrusion into its groundwater with a monitoring program and assessment for groundwater pumping.[56] Stanford University’s Woods Institute for the Environment identifies many positive strategies used by some local agencies:

> *measurable objectives for limiting groundwater drawdown; analyzing suites of management options with transparent decision criteria and simulations; collaborating with neighboring agencies; involving a broad range of agricultural, municipal, environmental, state, and federal stakeholders in their planning decisions; undertaking groundwater metering as well as monitoring; actively controlling pumping to limit groundwater drawdown; and protecting hydrologically connected surface waters and groundwater-dependent ecosystems.*[57]

Many jurisdictions, however, choose not to

Who Regulates Groundwater in California?

A variety of California agencies play a role in groundwater management.[53] At the local level, local water agencies are typically empowered to manage certain aspects of groundwater. The California Water Code defines more than 20 types of local agencies, including a Water Replenishment District and a Water Conservation District. The former can collect fees for groundwater replenishment programs. The latter can impose fees for groundwater extraction. Local agencies operate independently of state agencies, and do not need to report their activities to the Department of Water Resources (DWR). Some groundwater management districts in California operate under specific legislative authority, usually in response to evidence of overdraft conditions in a basin. The California courts manage other "adjudicated" basins.

At the state level, DWR provides technical assistance to local agencies, provides watermaster services for court-adjudicated basins, and monitors groundwater levels and quality. The State Water Resources Control Board (SWRCB), and in turn the nine Regional Water Quality Control Boards (RWQCB) are tasked with protecting the quality and supply of waters in California. SWRCB runs the Groundwater Ambient Monitoring and Assessment (GAMA) program,[54] which assesses water quality in wells throughout California. For individual domestic wells, GAMA is a voluntary monitoring program. California's Department of Public Health implements the federal Safe Drinking Water Act and regulates California drinking water systems. The California Department of Pesticide Regulation and the California Department of Toxic Substances Control protect groundwater from pesticides and other hazardous substances, respectively.

At the federal level, the U.S. Environmental Protection Agency regulates drinking water and surface water quality in coordination with California agencies. The U.S. Geological Survey and the U.S. Bureau of Reclamation both monitor groundwater levels and quality in parts of California.

submit plans or create insufficient, incomplete plans. Jurisdictions need not, under California law, review, update or implement their plans.[58]

Inconsistent groundwater management can be harmful and inefficient. Data gathering and monitoring of groundwater use and supply, discussed below, becomes more difficult when every local agency has its own methods for data acquisition. The Woods Institute observes that "[t]he lack of state oversight means that there is little easily accessible information about how these agencies plan for the development and management of groundwater resources."[59] California lacks even a comprehensive database of every local management plan.[60]

The last state survey on overdraft—a crucial concern for groundwater management—was done in 1980.[61] While many local agencies consider overdraft problems within their district, the impacts of overdraft at a statewide level remain largely unmeasured and unknown. And fragmented governance at the local level has, in some cases, made it difficult for local agencies "to wield the political and financial power necessary to mitigate conditions of groundwater overdraft."[62]

In addition, local management of groundwater in California today is not always adequate to protect this important resource. Local groundwater management plans lack sufficient scope to efficiently regulate regional water resources. Management at the watershed or groundwater basin level is sorely lacking. Coordinated management of surface water and groundwater is also lacking. The Woods Institute notes that while some jurisdictions have "taken a variety of promising approaches" to groundwater management, these management plans "do

Court-adjudicated water basins in California

Groundwater users have sometimes asked California State courts to determine each user's share of groundwater in a basin. A groundwater basin becomes **adjudicated** when a court decides the groundwater rights of all users. The court identifies the well owners and defines how much groundwater each owner can extract. The court assigns oversight to a Watermaster, who reports periodically to the court. Twenty-two groundwater basins have been adjudicated in California.[68] Adjudications can take years—the longest took 24 years—and can be quite costly.[69]

California is the only state that uses the **correlative rights system** to allocate groundwater use rights. In this system, the share of each landowner's groundwater right is based on the size of his overlying property. When adjudicated, landowners with large acreages receive the right to withdraw a correspondingly large maximum amount of the total groundwater share. This maximum amount may decrease, in the case of drought, for example. This correlative rights system is similar to what is often used to regulate oil and gas production.

Other states employ a **reasonable use rule** to allocate groundwater use rights. This rule gives priority to historical use, and limits new uses that would interfere with historical use. Courts or a regulatory agency typically decides what is a "reasonable" use.

Texas uses a **Rule of Capture** to manage groundwater. This gives each landowner the right to as much groundwater as they can capture and put to a beneficial use. Basically, the Rule of Capture operates as a first-come, first-served rule that encourages maximum utilization of groundwater. While malicious use is prohibited, landowners are not otherwise liable to other users for their withdrawal of groundwater under the Rule of Capture.

not constitute integrated regional management."[63] Even when local jurisdictions create innovative and effective groundwater management plans, these plans cannot fully address overdraft impacts on both groundwater and surface water users, developmental impacts on regional water resources, or conjunctive use of surface water and groundwater.[64] In addition, local agencies often focus their efforts quite narrowly on maintaining groundwater for consumption while ignoring other important goals, such as ecosystem restoration and minimizing third-party impacts.[65]

Because basins span local jurisdictions, local agencies are not always empowered to manage the basin effectively on their own. In many instances, various stakeholders have come together to develop a groundwater management plan for an entire basin. For example, the Turlock Groundwater Basin Association, made up of local agriculture, urban and county agencies, has developed a basin-wide management plan.[66]

In 2002, California passed SB 1938, which conditioned state groundwater grant money on implementation of a groundwater management plan that included several criteria. SB 1938 was meant to improve the quality and thoroughness of local government's groundwater management plans. These criteria include the adoption of monitoring protocols, periodic reporting, and groundwater management objectives. California, however, has no data on how many plans actually comply with the SB 1938 requirements.[67]

Adjudicated groundwater basins add a further inconsistency to California's groundwater management. Water quantity is inseparable from water quality. Adjudicated basins, however, focus on water quantity but overlook the equally important issue of water quality. Watermasters for adjudicated basins have authority to regulate groundwater extraction in order to keep within the estimated safe yield for the basin. But Watermasters have no authority to regulate extraction to protect water quality or prevent contamination of groundwater.[70] Other local and state agencies must be involved in protection of water quality. The result is an inconsistent management regime that fails to consider, at the same time, two major factors in groundwater availability: extraction rates and water quality.

B. The State Lacks Adequate Data on Groundwater Use And Quality

The "large amounts of water use being unregulated by the state" results in, as California Legislative Analyst's Office (LAO) suggests, "a lack of comprehensive data on statewide water use."[71] Part of the problem is a lack of data on groundwater use and groundwater quality in parts of the state, which limits the State's understanding of its groundwater resources. On groundwater use, the LAO has recognized, for example, that use of unreported groundwater resources by agriculture limits the ability of the State to directly assess agricultural water use.[72] On groundwater quality, the Public Policy Institute of California, a nonpartisan group devoted to research of major social, economic, and political issues, places compromised groundwater basins in the top 12 most likely changes that will affect California's water supply.[73]

California has recently made an effort to improve groundwater monitoring. In 2009, California passed SBx7 6 (Steinberg), which is meant to improve monitoring of groundwater elevations. (Groundwater elevation is the distance from the land surface to the groundwater, and can be used to estimate the amount of water in the groundwater basin.) The bill encourages local agencies to voluntarily start groundwater monitoring by January 1, 2012. These agencies report to DWR, which then releases a public report summarizing the information. The elevation data will also be made available on DWR's website.[78] If no local agency volunteers, DWR is required to monitor groundwater elevation in that jurisdiction. The SBx7 6 monitoring program does not cover groundwater withdrawals and groundwater quality.

SBx7 6 also prohibited entities from requiring property owners to submit groundwater monitoring information as part of the pro-

Other State Efforts to Monitor Groundwater: Arizona and Texas

California and Texas, uniquely among Western states, both lack a statewide policy requiring the metering, measurement and reporting of groundwater.[74] Texas relies on its state agency to monitor groundwater. Arizona, in contrast, imposes monitoring requirements on groundwater users. Unlike California, Texas and Arizona both make well data publicly accessible.

The Texas Groundwater Resources Division monitors the levels and quality of groundwater throughout the state.[75] The Division is responsible for modeling groundwater at a regional scale and maintaining water well records. Texas publishes daily water level data and groundwater quality sampling data online. Texas uses both annual monitoring of groundwater levels (from well data) and recorders that transmit near-real-time water level data via the Geostationary Operational Environmental Satellite (GOES) system. Texas' groundwater database includes data from 30 of its groundwater conservation districts, several cities and the U.S. Geological Survey.

Arizona strictly regulates groundwater wells through permitting, monitoring and standardized reporting requirements.[76] The State has a sampling program to characterize groundwater quality in designated groundwater basins.[77] Arizona's Department of Environmental Quality maintains a groundwater database and publishes reports summarizing the groundwater quality for each basin.

gram. Several local agencies, however, already have authority to require private property owners to submit such monitoring information as part of a more comprehensive groundwater monitoring program. The SBx7 6 prohibition will limit the State's access to this more comprehensive groundwater data and, according to one Senate analysis, "undermine the effectiveness of the program as a whole."[79]

SBx7 6 represents a good first step towards monitoring groundwater, but it is not nearly enough. Even with SBx7 6, California still lacks sufficient information on groundwater use and groundwater quality.

"California's legal conception of groundwater—distinguishing percolating water, subterranean streams, and surface streams—is inconsistent with the scientific understanding of how most groundwater interacts with surface water."

C. The Groundwater Rights System Does Not Reflect the Connection Between Surface Water and Groundwater

Lack of regulation of groundwater in California begins with the state's antiquated legal distinction between groundwater and surface water. Under California law, only percolating groundwater is considered "groundwater." Water flowing in a known and definite subterranean stream is legally equivalent to surface water. Appropriation of water from subterranean streams and surface water, but not percolating groundwater, generally require permits and are adjudicated under the California Water Code under the authority of SWRCB.[80]

This legal conception of groundwater—distinguishing percolating water, subterranean streams, and surface streams—is inconsistent with the scientific understanding of how most groundwater interacts with surface water. Among Western states, only California law still treats surface water and groundwater separately.[81]

Because of the interaction between surface water and groundwater, overuse of groundwater resources affects surface water users. Percolating groundwater often feeds into and draws from surface streams and rivers. Overdrafting reduces water flows in connected surface springs and rivers, negatively impacting related surface water ecosystems and surface water users. The Woods Institute recommends, therefore, that "[g]roundwater and surface water can be managed as interchangeable, with the choice between them depending on cost, relative availability and impact."[82] Groundwater depletion in California, for example, has dried up the Cosumnes River in the summer and fall, threatening migrating Chinook salmon.[83]

D. Poor Integration Between Surface And Groundwater Management Impedes Programs Meant to Increase California's Water Security

California has few restrictions on groundwater use.[84] To date, most groundwater is regulated at the local level.[85] Each groundwater user may drill a well and pump groundwater without a water right permit (although the driller must still comply with local ordinances and state recording requirements).[86]

Many have argued for better integration of surface water and groundwater policy in California. The Public Policy Institute argued for "[i]ncreased integration of surface water and groundwater," which it said "is essential for portfolio management of California's water resources."[92] The Institute recommends that groundwater rights be given legal parity to surface water rights.[93] Erin Schiller and Elizabeth Fowler, public policy fellows at the Pacific Research Institute, suggested that California must create secure groundwater rights, similar to surface water rights, in order to avoid overdraft that can occur if users can freely substitute groundwater for traded surface water.[94] The Association of California Water Agencies recently observed, in its framework for groundwater management in California, that "[s]ince surface water and groundwater resources can differ significantly in their availability, quality, cost and other characteristics, managing both resources together, rather than in isolation from each other, allows water managers to use the advantages of each for maximum benefit."[95]

Some have suggested that California adopt a state-local cooperative approach, similar to the "cooperative federalism" seen in many federal regulatory programs. The Woods Institute, for example, discussed a "cooperative federalism" approach whereby local governments are given the first opportunity to meet specific State performance goals, such as sustainable groundwater pumping and integrated groundwater and surface water management.[96] Barry Nelson, director of the California Vision Project for the Natural Resources Defense Council's Water Program, recommended that California provide a "a state-wide network of mandatory groundwater management programs. The State should establish minimum requirements for groundwater management plans and empower local agencies to write regional plans – with the state stepping in only if necessary."[97] The Public Policy Institute similarly recommended that "[t]he state's role should be to set deadlines and guidelines for local compliance, stepping in only where local entities do not step forward."[98]

In 2009, the California LAO recommended that the legislature consider "realign[ing] the water rights system"[99] and, over time, phase in "a state-administered water rights system for groundwater."[100] For groundwater, this means more comprehensive monitoring, statewide permitting for groundwater, and the establishment of management areas for high-risk areas for groundwater overdraft or pollution.[101] The statewide monitoring and permitting would allow for local control and local accountability for groundwater, because these local agencies are often the "first on the scene" when it comes to groundwater issues.[102]

Integration of groundwater and surface water management is necessary for the State's innovative water conservation and water efficiency programs. One example

Overview of the Legal Regime of Water Rights in California

There are three basic types of legal rights to use water in California: riparian, groundwater and appropriative rights. Each right is restricted and regulated by courts, California statutes and regulations, and the California Constitution. Importantly, the California Constitution requires that all water use be **reasonable and beneficial**. What constitutes unreasonable use of water may vary over time and depend on the overall context of the use.

A **riparian right** is the right to use water from a stream or lake adjacent to one's property. The right attaches to the land and typically cannot be transferred without selling the land. The right extends only to the natural flow of the stream and must be shared with other riparian rightsholders. Riparian rightsholders often file statements with California water agencies to document their water use rights.

Landowners share **groundwater rights** similar to the way they share riparian rights to surface streams: owners may engage in reasonable and beneficial use of groundwater and must share the water equitably. Unlike riparian rights, however, a user of groundwater may transfer that groundwater for use on lands that do not overlie the groundwater basin, so long as the overlying landowners in the basin are not harmed. Landowners above a common aquifer have **overlying rights** to the reasonable and beneficial use of the groundwater resource. In the case of groundwater shortage, these overlying rights take precedence over a user's right to transfer groundwater out of the basin.

Appropriative rights allow the user to divert or store water in a stream for their own purposes. While riparian rights are attached to the land, appropriative rights may be changed in purpose of use, place of use and points of diversion for any good reason. Appropriators do not share their water allocations as riparian right holders do in times of drought. Instead, water allocations are distributed by a priority system based on seniority of the claim. Because of this priority system, most appropriative rights holders file applications for permits with California's water agencies to protect their rights.

Groundwater Management: Arizona and Texas

Unlike California, Arizona and Texas both have groundwater management areas that cross local jurisdictional boundaries.[87] Within these management areas, specific rules govern groundwater withdrawal, use and storage. Typically, a permitting scheme is used to track water use. One goal of such a management area is to reverse overdraft within the managed groundwater basin. Arizona requires permits for groundwater use. California and Texas, on the other hand, are the only two Western states that do not have a state permitting system for groundwater.[88]

The Arizona Department of Water Resources (DWR) manages surface and groundwater resources within the state.[89] The Arizona Groundwater Management Code created Active Management Areas (AMAs) supervised by the Arizona DWR. Within each AMA, persons must have a groundwater permit to pump groundwater legally. Some water rights holders are exempt from permitting (grandfathered rights), as are wells that have very low pumping rates (de minimis use).

Texas allows areas to create Groundwater Conservation Districts (GCDs). Each GCD must develop and implement a groundwater management plan. Each plan sets goals for "providing the most efficient use of groundwater, controlling and preventing waste of groundwater, controlling and preventing subsidence, addressing conjunctive surface water management issues, addressing natural resource issues, addressing drought conditions, addressing conservation, groundwater recharge, and desired future aquifer conditions."[90] These GCDs are similar to the voluntary groundwater management districts allowed under California's AB 3030.

Texas has also created 16 Groundwater Management Areas, under the control of the Texas Water Development Board, "to provide for the conservation, preservation, protection, recharging, and prevention of waste of the groundwater, and of groundwater reservoirs or their subdivisions, and to control subsidence caused by withdrawal of water from those groundwater reservoirs or their subdivisions . . . ."[91] These management areas cross local district boundaries.

"There's no groundwater law in this state to speak of, which is an abomination in my opinion, and it really complicates water management."

— Peter Gleick, co-founder and president of the Pacific Institute

is in agricultural water use. As water expert Peter Gleick explains: "There's no groundwater law in this state to speak of, which is an abomination in my opinion, and it really complicates water management. So, you raise the price of water to a farmer to a point when they decide they're going to pump groundwater instead, because it's cheaper."[103] Even if users are not charged directly for surface water use, users incur costs if-they must implement conservation or water efficiency technologies, such as installation of low-flow toilets or drip irrigation.* These indirect costs increase the value of surface water and subsequently increase groundwater exploitation. Even if use of drip irrigation would save the farmer money over the long-term, he may still choose the cheaper short-term solution: substitution of unregulated groundwater in place of increasingly expensive surface water.

Another example is groundwater banking. Such banking, however, has been hampered by several lingering legal uncertainties. These include the archaic separation

* Irrigation technology such as drip irrigation is properly seen as a water efficiency measure, but not necessarily a water conservation measure. Because irrigation runoff typically recharges groundwater basins in California's Central Valley, reduction in the water used for irrigation will reduce groundwater recharge. See, for example, Lund et al., "Taking agricultural conservation seriously," Cal. WaterBlog, Mar. 15, 2011. http://californiawaterblog.com/2011/03/15/taking-agricultural-conservation-seriously/. Nevertheless, there are numerous benefits to increased water efficiency in agricultural, including a reduction of fertilizer and pesticide runoff that harms the environment and can poison California's water supply. In addition, reduction in irrigation runoff through water efficiency measures can leave more water in California's streams and rivers. There are many ways to increase groundwater recharge; using runoff from irrigation is not an efficient or particularly effective means to do so.

How does Groundwater Substitution Work?

Groundwater substitution means that the water user chooses to forgo surface water use by substituting an equivalent amount of groundwater use. The water user then may transfer the "saved" surface water. To compensate for poor monitoring and lack of statewide permitting of groundwater use, DWR and the U.S. Bureau of Reclamation require significant documentation for proposed groundwater substitution transfers.[106]

The four basic components of such a proposal are: (1) location and characteristics of the groundwater pumping wells; (2) volume and schedule of groundwater pumping related to the transfer; (3) a monitoring plan; and (4) a mitigation strategy to address third-party impacts.

Sellers must comply with local groundwater management plans, other local requirements, any adjudications, and overdraft protections. Transfers based on groundwater substitution must also not "unreasonably affect fish, wildlife, other instream beneficial uses, or the environment and [must] have no significant unmitigated environmental effects."[107]

of surface water rights and groundwater rights systems (discussed in Part IIC above), as well as questions about local landowners' rights to exclude others from using the aquifer space beneath their lands for storage of imported water."[104] LAO suggests that groundwater storage could be a cost-efficient mechanism to improve California's water supply in the short-term, but only if groundwater is properly regulated and monitored.[105]

E. The Water Transfers Program Creates Perverse Incentives To Use Groundwater

One technique for dealing with limited water supplies is to give farmers incentives to use less water. Giving farmers the ability to sell their conserved water is one such incentive. Farmers are paid to conserve or limit their surface water use, and that conserved water is transferred to another user, such as an urban water agency.

DWR and the U.S. Bureau of Reclamation have cooperated to create a Water Transfers Program for California. In 2010 and 2011, these two agencies approved and facilitated three types of water transfers. One of these permitted transfers was groundwater substitution. A farmer could forgo the use of surface water and instead use groundwater. The farmer could then transfer (sell) the saved surface water to another user.

Conjunctive use of groundwater and surface water can provide real benefits to farmers and other water users, such as improved water supply during drought years. This type of groundwater substitution, however, does not usually result in any actual water saved. Groundwater substitution of surface water supply can lead to groundwater overdraft, land subsidence, higher pumping costs for other groundwater users, water quality degradation, and lower connected surface-water flows.[108] And because water transfer programs tend to be used most during dry years—when water demand is greatest—any such transfer program in California needs to account for the fact that groundwater use makes up, on average, 39% of California's water supply in dry years.[109]

In Australia, there is some evidence that surface water trading indirectly increased groundwater extraction in cases where irrigators opportunistically sold surface water entitlements or allocations and replaced that surface water with groundwater. Trading in groundwater allocations have increased from 2–5% to 10–20% of total water use in some parts of Australia.[110]

The problem with California's Water Transfers Program is that California lacks the type of groundwater monitoring and enforcement that would be necessary to ensure that the program does not result in groundwater overdraft or harm to third parties. To their credit, DWR and the U.S. Bureau of Reclamation do require significant documentation, including a monitoring and mitigation plan, for proposed groundwater substitutions. But the calculation of the amount of water available for the substitution relies on hypothetical estimates of past baseline use and acreage estimates instead of using verifiable groundwater and surface water use data. This is because California lacks adequate use data. The Water Transfers Program attempts to compensate for lack of adequate monitoring and water use regulation with mostly unenforceable estimates and promises of mitigation. California's Water Transfers Program is innovative and has the potential to significantly benefit California's water supply, but it is ultimately hampered by the need to impose a regulatory scheme on groundwater one user at a time.

III. Recommendations

Managing California's limited water supply requires first effectively managing California's groundwater. This paper recommends a framework of state-local cooperation for groundwater management. The State should establish enforceable standards and goals for monitoring, data reporting and management of groundwater basins. Regional and local agencies choose how best to comply with these standards and goals. In the absence of regional or local agency compliance, the State can choose to intervene to enforce these standards and goals.

To that end, California should prioritize the following goals:

(A) Establish comprehensive groundwater monitoring, including metering of groundwater use and monitoring of groundwater levels and quality. Monitoring data from state and local agencies should be publicly available at a statewide level.

(B) Implement statewide rules for regional regulation of groundwater, wherein local jurisdictions are given clear guidelines and mandatory management goals.

"Pumping groundwater without monitoring extraction or the state of the aquifer has been compared to a business continually withdrawing money from a bank account without any bookkeeping system."

— Rebecca Nelson, Woods Institute for the Environment

Understanding the status of groundwater basins throughout California is the first step in an effective management regime. Accurate metering of groundwater use is an example of the benefits of a state-local cooperative framework. The state has the ability to establish metering standards and coordinate data submission from a variety of local and regional agencies. Localities are best placed to respond to local concerns in establishing their monitoring programs. While some monitoring of groundwater is done throughout the state, California could do more to establish sophisticated water quality and water use monitoring that is readily available to the public, state and local agencies.

Regulation of groundwater use and protection of groundwater quality must occur at the basin-wide level, which means regulation will often be regional, not just local. Here, the State could coordinate local efforts and ensure that water use in groundwater basins remains sustainable. The State should create a framework for allocating water rights within groundwater basins and make necessary changes to the California Water Code to allow for permitting and enforcement of groundwater rights by statute. Regional and local entities can then use that framework to allocate groundwater rights and ensure that groundwater extraction in each groundwater basin remains sustainable.

A. Establish Comprehensive Monitoring of Groundwater

As the LAO pointed out in its 2010 report, "The state needs, but now lacks, comprehensive data on groundwater extraction, ground water levels, and groundwater quality."[111] Such data is a prerequisite to an effective permitting system for groundwater,[112] and a prerequisite to allowing groundwater users to bank or transfer groundwater either directly or indirectly. As the Woods Institute notes, "[p]umping groundwater without monitoring extraction or the state of the aquifer has been compared to a business continually withdrawing money from a bank account without any bookkeeping system."[113] Therefore, California should seek to implement the following measures to promote comprehensive statewide monitoring of groundwater, so that we can effectively protect water supply and quality for future years.

1. Require Accurate Metering of All Groundwater Use

Practically every other state in the Southwest requires some form of reporting for groundwater withdrawals.[114] Even in agricultural use of groundwater, where irrigation runoff may be expected to recharge the groundwater basin, there are economic and environmental benefits to more efficient water use. Quantifying water use can lead to better valuation of water use and better prevention of overdraft conditions in California's groundwater basins.

Groundwater users have reasons to support groundwater metering. Groundwater is a shared resource. Each overlying landowner has equal rights to use the groundwater. Monitoring helps to identify those who may be using more than their fair share and thereby protects the groundwater rights of all overlying landowners. Metering also facilitates landowners who wish to sell a portion of their groundwater, substitute surface water use with groundwater, or participate in a groundwater banking scheme. Metering does not necessarily require that users be charged for groundwater use. But metering

"California should assist local water districts by creating a set of minimum standards for collection and reporting groundwater data."

does help users to benefit from and protect their groundwater rights.

Both residential and agricultural users of groundwater should be metered. Agricultural users should not be allowed to use irrigated acreage as a proxy for groundwater metering. Such a proxy requires complicated estimates of water conservation measures and water use by crop and region,[115] increasing the administrative burden on the regulatory agency. Such a proxy also fails to directly reflect efforts by the farmer to decrease water consumption and use water more efficiently. As discussed below in Part III.A.4, satellite monitoring may allow for an alternative means of measuring groundwater use for large-acreage farms.

Local water districts would also need to establish a standardized system for compiling water use data from the meters. Meters could be checked on monthly intervals, similar to how electric and urban water use is metered. Or the meters could report real-time water use information to a central server, obviating the need for monthly site visits. Monitoring of meters would require a source of funding, because not all groundwater use is currently billed. AB 2572 (Kehoe, 2004) requires all urban water suppliers to install meters by 2025.

One excellent example of a city water metering program is in Lodi, California, which relies on groundwater for some of its water supply.[116] The town is requiring all property owners to install water meters. Each water meter takes 10 to 30 minutes to install. Property owners can pay for the installation either in a lump sum ($300) or in installments ($8.52 per month) over three years. Alternatively, owners can choose to defer the fee, via a property lien, until the property is sold. California should consider similar funding options for a groundwater metering program.

As part of any water metering system, California must establish clear, mandated accuracy standards for water metering equipment. California regulates the accuracy of gas pumps and electric meters, to name two examples. Water meters should also reflect an appropriate accuracy standard. Otherwise, water use data loses its value as an estimate of California water use.

2. Require Local Water Districts to Submit Standardized Data on Groundwater Elevation, Use and Quality

California has begun moving towards state-standardized monitoring of groundwater elevation with SBx7 6. Sacramento Groundwater Authority, Western Placer County, and Butte County have all developed a network of monitoring wells for groundwater elevation, measured either continuously or at periodic intervals throughout the year.[117]

Nevertheless, California lacks access to high-quality data on groundwater elevation, use and quality. The State particularly needs better monitoring of groundwater use and groundwater quality. Basic data on the supply and quality of this publicly shared resource should be a primary goal for California.

Fox Canyon Groundwater Management Authority, for example, requires owners to report groundwater use twice annually—measured through metering of wells—with the exception of domestic use on land of one acre or less.[118] Monterey County Water Resources requires certain agricultural, urban and industrial users to report their groundwater use on an annual basis.[119] The Central Valley RWQCB plans to integrate farm groundwater monitoring into its surface water runoff monitoring.[120] It will look for nitrates, pathogens and pesticides and require farm evaluations. The monitoring is split into three tiers, with monitoring requirements increasing in areas with water quality threats or known water quality problems.

Reporting requirements for groundwater elevation should be strengthened. Currently, local monitoring associations must report only what they determine is a representative sample of the groundwater wells twice per year, beginning in January 2012.[121] Failure to comply means a potential loss of eligibility for state grants and loans for water projects. And, as discussed above, local regions are not mandated to measure groundwater elevations. The voluntary nature of SBx7 6 along with its exemption for property owners limits California's ability to track its groundwater supplies.

As discussed above, local water districts should be required to monitor individual user groundwater use. Furthermore, local water districts should also survey and report on groundwater quality. Urban water utilities are generally required to monitor drinking water quality, but monitoring of groundwater in rural areas is less widespread. Furthermore, the LAO observed that groundwater contamination is often known to local, but not state, water managers.[122] And groundwater contamination can be costly to clean up,[123] and thus is better caught and mitigated as early as possible.

One potential source of groundwater data is a Well Completion Report, which must be submitted to DWR whenever a new well is dug or an existing well is modified.[124] Currently, the California Water Code keeps these reports confidential. Instead, the Code should be changed to allow DWR to publish summary information from these reports, with reasonable protections for owner anonymity and exceptions for strategic oil and gas wells. These well reports are invaluable sources of information on hydrology within the state. California should support Senator Fran Pavley's proposal, SB 263, which would increase public access to well completion reports.

As the Woods Institute points out, problems with comprehensiveness and accuracy are common to groundwater monitoring systems throughout the state.[125] Variation in monitoring water quality is another common problem. "Using standard data collection and management methodologies or protocols to ensure that the data collected are accurate and consistent is as important as monitoring."[126] The LAO similarly recommends that California "phase in a comprehensive groundwater monitoring program over a period of years modeled after the best such measures adopted by other western states."[127]

California should assist local water districts by creating a set of minimum standards for collection and reporting groundwater data. Gillibrand Groundwater Basin, for example, has established standards for groundwater data collection, covering measurement instruments and frequency, quality assurance, and data reporting.[128] Local districts not in compliance with these minimum standards would be ineligible for state funding, as with SBx7 6. Furthermore, DWR should be given responsibility and authority to collect groundwater use and groundwater quality data if local districts fail to meet these minimum standards.

3. Implement Real-Time Monitoring And Periodic Surveys Of Groundwater Quality

Outside of municipal areas, groundwater quality monitoring is often overlooked. Monitoring groundwater quality can be split into two important aspects. First, real-time monitoring for certain contaminants can provide early warning of groundwater contamination. Second, periodic surveys of groundwater quality can take a more comprehensive look at contaminants in California's groundwater.

For example, U.S. Geological Survey is conducting a study that analyzes groundwater for concentrations of pesticides, solvents, gasoline nutrients, radioactivity and certain microbe indicators.[129] These periodic surveys should also examine environmental impacts on groundwater-dependent ecosystems. With technical and monetary assistance from the state, local agencies could implement both aspects of groundwater monitoring.

Use of state funds and bond funds for water projects, such as drinking water improvement, should be tied to improvements in monitoring and surveys of groundwater quality. Such projects should include a long-term commitment to monitoring and periodic groundwater quality surveys. In particular, groundwater recharge areas should be closely monitored and protected from contamination. Assemblymember Huffman has introduced a bill, AB 359, that would require local agencies to map and publicly disclose groundwater recharge areas as part of their AB 3030 groundwater management plans. More is needed, however, in order to survey the extent of groundwater contamination in the state and to protect basins from future contamination.

"Water replenishment districts have not prevented overdraft and groundwater contamination throughout California. More is needed to protect California's groundwater supply."

4. Encourage Further Development and Use of Satellite Monitoring of Groundwater

Launched in 2002, the NASA/German Aerospace Center Gravity Recovery and Climate Experiment (GRACE) is comprised of twin satellites that measure precise monthly changes in Earth's gravity field.[130] GRACE can see changes in water content in Earth's reservoirs. In 2009, scientists from NASA and UC Irvine presented research using GRACE to measure groundwater depletion in California's Sacramento and San Joaquin basins. According to Jay Famiglietti, director of the UC Center for Hydrologic Modeling, "GRACE data reveal groundwater in these basins is being pumped for irrigation at rates that are not sustainable if current trends continue."[131]

California water agencies should work with the UC Center for Hydrologic Modeling to further develop this satellite monitoring technology. One of the scientists involved with the GRACE Project at NASA's Jet Propulsion Laboratory, Michael Watkins, noted that "[b]y providing data on large-scale groundwater depletion rates, GRACE can help California water managers make informed decisions about allocating water resources."[132] GRACE offers an independent data source for California water managers, one that can be used to independently measure the effectiveness of groundwater management plans throughout California.

5. Integrate Groundwater Data into the California Water Plan and Create a Publicly Accessible Statewide Database

If local water districts are required to submit standardized data on groundwater use, quality and extraction, as recommended above, then California should take full advantage of that data. Real-time monitoring and periodic surveys should also be accessible at a statewide, public level. DWR has begun this task with its online Water Data Library,[133] which contains data on groundwater level and water quality for monitoring stations throughout the state. And DWR's Bulletin 118, last updated in 2003, provides a good overview of water quality and water use in groundwater basins throughout the state.

LAO recommends that DWR compile and integrate such groundwater data into the California Water Plan.[134] A recent UC Berkley / UCLA Law report on water and energy use also recommended that the State "create and maintain a centralized database of information on water consumption."[135] Groundwater data would be a valuable part of any such database.

Senator Pavley recently introduced a bill (SB 571) that would make the California Water Commission an independent agency and revise the requirements of the California Water Plan. As part of those revisions, the bill should prioritize integration of groundwater data. SWRCB already has some authority over surface water or surface water planning; it should have the same level of authority over groundwater and groundwater planning.

In addition, California should establish a publicly accessible statewide database for this groundwater data. San Benito County and Santa Clara Valley Water Districts, for example, both provide public access to an annual electronic report on groundwater resources.[136] Butte County has developed a website for monitoring and reporting groundwater information, along with interactive maps of monitoring wells.[137] All groundwater data submitted by local agencies should be made available to the public in a searchable online database. Appropriate measures should be taken to anonymize any data on individual groundwater use.

B. Establish State Standards for Regional Management of Groundwater

Once monitoring is in place, the next step is to determine how to best integrate groundwater management with the surface water permitting scheme. Voluntary local groundwater management has had many historical successes but is insufficient in the face of California's water need. In many areas—though certainly not all—local groundwater management has not prevented overdraft, has not adequately addressed the connection between surface water and groundwater, and is limited to local jurisdictions when the water resource in question often spans

"California should allocate groundwater rights in all basins, relying on local or regional agencies to identify rights holders and allocate their share of groundwater use."

jurisdictions. Instead, California should exert more control at a state level over groundwater management.

The Water Replenishment District Act, signed in 1955, allowed regions to form water replenishment districts.[138] These districts have authority over replenishment, protection, and preservation of groundwater supplies. The districts prepare annual engineering surveys of groundwater supplies. Such districts can also impose an assessment based on groundwater production in order to pay for groundwater replenishment or contaminant removal. This assessment, however, must comply with Proposition 218, which requires a vote of affected property owners before the assessment can be levied.[139]

One approach to statewide groundwater management is to establish comprehensive, statewide rules for groundwater use. Groundwater regulation has very local implications, however, and California has a long history of local management for groundwater. Without significant local input, however, this approach risks being a "one size fits all" approach that is ill-suited to the varied regional water conditions in California.

A second approach is to create a template for statewide rules and management goals, and then let local or regional agencies either adopt the statewide template or submit their own equivalent set of rules. If DWR (or another designated agency) determines the local districts groundwater management rules will achieve the management goals, then the local district can implement its own rules. Local governments that fail to develop an adequate plan risk losing their management authority, with the State stepping in to develop a management plan in those instances. The State cannot, however, merely set deadlines and guidelines. It must take an active role in developing a framework for groundwater monitoring and regulation, impose enforceable standards and goals, and hold localities accountable for their groundwater management plans.

This second approach is the most likely way forward for California. SBx7 6 has already moved California in this direction, by requiring DWR to monitor groundwater elevation if no local agency volunteers to do so. State oversight of groundwater is necessary to promote the necessary integrated management of surface and groundwater resources at a regional level. But many local districts have developed sophisticated and innovative groundwater management plans of which the State should take advantage. As recommended above, the creation of comprehensive, consistent data on groundwater elevation, use and quality will promote regional integrated management of California's water resources. And no matter which approach is followed, the following measures should be considered essential elements for regulating groundwater.

1. Allocate Groundwater Rights In All Basins, Not Just Adjudicated Basins

California cannot afford to wait until every groundwater basin becomes overdrafted and adjudicated by the courts. Instead, California should allocate groundwater rights in all basins, relying on local or regional agencies to identify rights holders and allocate their share of groundwater use.

This allocation follows the state-local framework discussed above: the State establishes a framework for allocating groundwater rights and localities decide the specifics on allocation of those rights. Monitoring of groundwater use, discussed above, is a crucial first step in this eventual allocation of groundwater rights, because it can establish a valid baseline of groundwater use in each basin.

LAO believes that state administration of groundwater rights would result in long-term cost savings to public and private entities due to avoidance of costly adjudications, cleanup of degraded groundwater, and groundwater treatment.[140]

California could choose to implement a permitting system, a licensing system or an entitlements system to regulate and limit groundwater withdrawals. The goals of any such system should be to prevent overdraft, assign the right to withdrawal groundwater in an equitable manner, and promote administrative efficiency. This paper considers an entitlement/allocation system for distributing groundwater rights, as discussed below.

"The sustainable yield should aim to keep groundwater withdrawal within the natural recharge rate of the basin over a long-term period."

2. Enforce Legal Restrictions on Groundwater Use and Prevent Unmonitored Withdrawals

All basin-wide groundwater management plans should include an enforcement plan to ensure that groundwater withdrawals are monitored and restricted to legal limits. Mendocino City Community Services District, for example, requires new wells to be metered. The District has the right to collect meter information and rescind permits for violations. California should be prepared to step in to enforce legal restrictions on groundwater use in districts that do not implement adequate enforcement measures. Ideally, the State would also provide funding for districts that do adequately enforce groundwater use limitations.

Fees or tiered pricing for large groundwater users is one way to raise the necessary funding for administration and enforcement of groundwater rights. Orange County Water District uses a "pump-and-pay" system based on usage to fund administration of groundwater and replenishment efforts.[141] Fox Canyon Groundwater Management Agency penalizes those who extract more than their allocated share of groundwater, and its management plan calls for the penalties to be used to purchase replacement water.[142] Soquel Creek Water District charges residential, commercial and agricultural users on a tiered pricing rate for its groundwater distribution systems.[143]

3. Determine And Enforce A "Sustainable Yield" for Groundwater Withdrawal in Each Basin

Groundwater basins are not infinite resources of water. Instead, the basin recharges slowly each year, depending on precipitation levels and other factors. Furthermore, excess extraction from a groundwater basin can have adverse effects on the overlying land (causing subsidence) and the holding capacity of the basin. Therefore, groundwater extraction should be regulated and either a state or local agency should, each year, set an allocation for total withdrawals from each basin based on a long-term sustainable yield and annual water supply conditions. (In adjudicated water basins, the court has defined the safe yield for the basin at issue.)

Such a sustainable yield should permit groundwater withdrawal that does not exceed the recharge rate of the basin, with an appropriate, and conservative, margin of error. The sustainable yield should aim to keep groundwater withdrawal within the natural recharge rate of the basin over a long-term period, such as the five- or ten-year average. And the yield should allow for increased withdrawal in drought years, in exchange for decreased withdrawal in wet years to permit sufficient recharge of the basin. While the State should play a strong role in setting the basic parameters of this sustainable yield concept, it would be regional or local agencies that in fact define the yield and set annual allocation amounts for each basin. This is necessary because different groundwater basins exhibit very different recharge characteristics. This necessitates different considerations, and different sustainable yield levels, for different basins.

In Australia, a government review recommends a similar approach to its regulation of groundwater. The Australian review recommends that "the environmental impacts of groundwater trading should be considered in the context of overall groundwater management that seeks improved environmental outcomes by setting the sustainable yield for each aquifer."[144] Once one determines the sustainable yield of an aquifer, transfers in and out of the aquifer can be incorporated into a sustainable management policy for the aquifer.

The Central Sacramento County groundwater management plan, for example, defines a long-term average extraction rate (273,000 af/yr) meant to avoid undue risk of harmful consequences from groundwater overdraft by keeping within the natural recharge rate.[145] Central Sacramento's long-term annual limit, however, is not without its problems. It does not account for uncertainties and is based on historical hydrological data, not future projections that would factor in potential climate change impacts. And it was developed as a "negotiated limit" among stakeholders that does not account for impacts to third parties, such as the environmental benefits of groundwater or the impacts to surface water users.

4. Remove The Legal Distinction Between Percolating Groundwater and Subterranean Streams

Only California applies a different legal regime to groundwater than surface water.[146] Cal. Water Code § 1200 limits the appropriative right to surface water and subterranean streams. This paper recommends, as LAO does,[147] removing the legal distinction between percolating groundwater and subterranean streams, because groundwater is inextricably linked to surface water.

As the Public Policy Institute points out, these legal changes will likely be an incremental process, dependent on legislative action.[148] Today, SWRCB has some authority to address the relationship between groundwater use and river flow, as it has done in its regulation of frost protection methods in the Russian River Valley.[149] In the near term, minor changes to the Water Code could give SWRCB more authority to account for groundwater availability and regulate pumping. In the longer term, larger changes to SWRCB's authority could be envisioned. Under a narrow grant of authority, the SWRCB would only adjudicate groundwater as it does surface water. Under a broader grant of authority, the SWRCB would regulate groundwater under a permitting and rights system.

California could change the definition of § 1200 to include groundwater as an appropriative right. This change, however, would bring with it the complicated priority scheme of appropriative water rights. But it would also bring a statewide permitting system for groundwater use and an established method to quantify groundwater rights for users.

Alternatively, California could treat groundwater as a riparian right. Because groundwater use has historically been tied to the overlying land and shared equally among all users, it may be better thought of as a riparian water right. Riparian rights, however, are not transferable to another parcel of land. This hard link between the adjacent land and the water right would limit the ability of the State to establish an entitlement/allocation scheme to efficiently limit and regulate groundwater use.

This paper recommends that groundwater be considered an appropriative right. This would bring groundwater regulation more in line with surface water regulation in California, and allow for conjunctive use of surface water and groundwater under the same permitting framework. To protect against overdraft, however, California should develop a permitting system for groundwater that relies on tradable entitlements and allocations for groundwater use.

As with the introduction of surface water permitting in California, groundwater users should have incentives to participate in the permitting scheme. Quantification of a groundwater right could benefit many groundwater users in the long term. The ability to participate in a groundwater banking or conjunctive use scheme could also be an incentive for permitting. Such incentives can help California avoid the often multi-decade legal struggles that have accompanied court adjudication of groundwater rights in some basins. An entitlement/allocation scheme, discussed in detail below, could be managed by regional or local agencies under a state framework. Such a system could be used to adequately protect a basin from unsustainable extraction and enforce the sustainable yield in light of a basin's specific recharge characteristics. It would provide groundwater users with flexibility to sell or purchase rights to groundwater as their needs change. And it could be incorporated into the permitting system already in place for appropriative rights.

5. Allocate Groundwater Through Groundwater Entitlement Shares for each Basin In California

Instead of fully applying either the appropriative or riparian water rights management schemes for groundwater, California should create a system of entitlements and allocations to regulate groundwater use. This system could be used to limit groundwater use to the sustainable yield level in an efficient manner. If successful, this system could also be expanded to include surface water use in the future.

An entitlement represents the right of the groundwater user to withdraw a proportional share of the basin's annual sustainable yield. An allocation represents a portion of

How Water Entitlements and Allocations Work

Other water rights programs, such as in Australia, distinguish between entitlements and allocations of water rights. Similarly, court-adjudicated basins in California typically have assigned groundwater rights and annual allocations. Water users own entitlements, allocations, or both, and, ideally, can freely trade these rights. These entitlements and allocations are similar to the assignment of individual fishing quotas in some fisheries.[150]

An **entitlement** is an ongoing right to exclusively access a share of water from a specific pool. In the case of groundwater, an entitlement share represents a percentage of the total groundwater available for withdrawal in the underlying groundwater basin.

An **allocation** is a specific volume of water assigned annually for each entitlement share. Each year, the water agency determines the sustainable yield, representing the total amount of water that may be withdrawn by owners of groundwater entitlement shares. That total yield is a volume of water that is allocated to each entitlement holder. Thus, the allocation varies by year, depending on groundwater conditions.

For example, a groundwater user may hold 2 entitlement shares, giving him the right to a yearly allocation of groundwater in the basin. Suppose each entitlement share represents the right to 1% of the sustainable yield from the basin. In a given year, the sustainable yield may be set at 1 million gallons. A holder of 2 entitlement shares would then receive an allocation of 20,000 gallons (2%) for that year. Groundwater withdrawal would require the user to retire an equivalent amount of allocation shares.

If the owner needs only 10,000 gallons, he may choose to sell his remaining allocation (10,000 gallons) to another user in the basin. That other user then receives the temporary right to withdraw 10,000 gallons for that year only. New groundwater users entering the basin would need to acquire entitlements or annual allocations from other users.

the annual sustainable yield of a groundwater basin, assigned to entitlement holders on a periodic basis.

Allocation of entitlement rights can be done by either equal share or historical use. Traditionally, groundwater has been allocated equally to all users. In either case, SWRCB could establish a permitting scheme, similar to that used for post-1914 surface water appropriation rights. SWRCB, or a designated local agency, would assign entitlements in the form of shares to groundwater rights holders. Each share of an entitlement would grant the user an annual allocation of the sustainable yield of the groundwater basin. Entitlements could be allocated on either an historical use average or an equal share basis. Within a groundwater region, these allocations and entitlements should be freely tradable.

Mendocino City Community Services District, for example, requires anyone seeking to extract groundwater for a new development or expansion of existing use to obtain a permit. Under an entitlement system, such an expansion of groundwater extraction would require acquisition of an appropriate amount of entitlement shares.

Conceivably, one could store additional surface water in the groundwater basin. This is considered groundwater banking. In an entitlement/allocation scheme, groundwater banking creates additional allocations for that user (minus an appropriate amount to account for water loss with the banking technology). When the user withdraws water from the basin, that withdrawal is credited against these additional allocation shares generated from the banking.

Conclusion California cannot afford to ignore groundwater management. Without monitoring, regulation and allocation of groundwater rights, existing and future programs to encourage water efficiency and conservation will continue to be undermined.

Many local jurisdictions, however, have developed innovative, effective strategies for managing their groundwater. The State should draw on these programs when establishing enforceable standards for monitoring groundwater levels, use and quality. The State can also assist these exemplary local jurisdictions by making long-overdue, targeted changes in the California Water Code to recognize the physical connection between surface water and groundwater. A state-local cooperative framework for groundwater regulation has the potential to address groundwater overdraft and groundwater pollution, with the promise of better water security for California's future.

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